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Research Paper

Does straw mulch partial-removal from soil interfere in yield and industrial quality sugarcane? A long term study

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ABSTRACT

Sugarcane straw mulch left in the field after its mechanical harvest has become very valuable raw material for second generation ethanol and bioelectricity production. However, little information is available on how much straw mulch is needed to be left in the field so that agricultural productivity is not affected and high sustainability is provided for the bioenergy production system. The objective of this work was to evaluate the productivity and industrial quality of sugarcane after five years of cultivation when different amount of straw mulch is removed from the field. The experiment was installed in clay texture Eutroferric Red Latosol (Oxisol). Six treatments were evaluated: 0%, 25% (5 t ha^{-1}), 50% (10 t ha^{-1}), 75% (15 t ha^{-1}), 100% (20 t ha^{-1}) of straw mulch and burnt cane harvesting (where 100% of the straw mulch was burned). Evaluated parameters included sugarcane productivity (tons/hectare) and its industrial quality (Pol, soluble solids (°Brix), apparent purity and total sugars (TS)). Productivity was calculated at the end of the cycle whereas industrial quality parameters were evaluated during three phases i.e. 180, 240 and 350 days after cutting (DAC). Straw mulch of 50 and 75% were statistically at par with each other but resulted in higher sugarcane production with 47% more productivity as compared to 0 and 25% of straw mulch as well as burned cane harvesting. Straw mulch didn't affect the industrial quality; however, higher sugar production was supported by higher agricultural productivity, under low moisture condition. It is possible to remove 50% of straw mulch from the field for the production of second generation ethanol or bioelectricity, without any damage to the crop.

1. Introduction

Increasing global need for food and energy requires more sustainable mode of production in the most diverse sectors. In this sense, ethanol as a substitute for fossil fuels meets these global requirements due to its effectiveness in economic and environmental terms (Carvalho et al., 2016a). It is necessary for Brazil and United States (major world producers of ethanol) to increase their production from the current 80 to approximately 200 billion liters to meet the global demand of biofuel in 2021 (Goldemberg et al., 2014).

Sugarcane is grown in over 121 countries and is a good source for sugar and ethanol production. Over 80% of sugar produced in the world is obtained from sugarcane, whereas Brazil, India, China and Thailand account for 60% of the total production (Food and Agriculture Organization of the United Nations (FAO), 2016). In addition, ethanol from sugarcane is considered one of the world's purest biofuels (EMBRAPA, 2017). The major sugarcane producing areas of the world have recently adopted the practice of mechanical harvesting (Cardoso et al., 2013; UNICA, 2013), where sugarcane leaves and tips are cut off and left over the soil surface to form a mulch called straw mulch. More than 300 million Mg of straw mulch is produced per year worldwide (UNICA, 2013) that can be utilized to increase the production of ethanol (Carvalho et al., 2016b) or bioelectricity without increasing the area of cultivation.

One ton of straw mulch can produce 270 l of ethanol while one ton of sugarcane can produce 80 l of ethanol (Santos et al., 2012). In

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addition, it has great potential for bioelectricity generation as well. Brazil is leading the world in renewable electricity generation that fulfills 40% of the country's electricity demand, of which 16% comes from sugarcane bagasse (EPE, 2015), and straw mulch has twice the potential for energy generation than bagasse (Udop, 2017). Although straw mulch is an effective raw material for the production of ethanol, bioelectricity and others (Costa et al., 2013) but its indiscriminate removal from the field can not only reduce its positive effects on sugarcane made products (Resende et al., 2006; Anjos et al., 2017) but also on the sustainability of the production system (Christoffoleti et al., 2007; Garbiate et al., 2011; Silva et al., 2012; Sousa et al., 2012). Thus, the impact of straw mulch removal on productivity and the industrial quality of the crop should better be studied for its accurate management.

Straw mulch over the soil surface brings certain chemical, physical and biological changes in the agricultural environment, such as increase in the soil organic matters, decrease in the thermal fluctuations of soil superficial layers, increase in the water permeation with low evaporation, erosion control, increase of macro and micro fauna and changes in the weed flora (Inman-Bamber and Smith, 2005; Garcia et al., 2007; Christoffoleti et al., 2007; Cavenaghi et al., 2007; Guimarães et al., 2008; Tavares et al., 2010; Cardoso et al., 2013; Costa et al., 2014). These changes directly impact the development, productivity, industrial quality and longevity of sugarcane (Souza et al., 2005a).

Felipe (2010) points out that sugarcane juice (water (75–82%) and soluble solids (10–25%)), can be improved since it is influenced by several factors which compromise the final quality. Among these factors, few of the main include: crop management, soil moisture and temperature, harvesting system and climatic conditions. Accordingly, Souza et al. (2005a) verified that straw mulch incorporation to the soil at a depth of 0.30 m reduces total sugars and sucrose of sugarcane ratoons.

Several studies have reported the advantages of keeping straw mulch over the soil surface (Ball-Coelho et al., 1993; Resende et al., 2006). However, in some cases there was a difficulty in the plant emergence, causing regrowth failure and ultimate low yield (Campos et al., 2008; Campos, 2010). It is important to mention that studies on this subject do not address how much straw mulch would be sufficient to obtain such benefits or if the negative effects on the ratoon would be the same if smaller quantities were left over the soil surface. So, works are of prime importance which classifies the necessary amount of straw mulch that can be used as mulch over soil surface and which can be useful for soil-plant system, whereas the surplus can be used for the production of ethanol or bioelectricity, aiming at a sustainable global production of sugar and energy.

The objective of this work was to evaluate the productivity and industrial quality of sugarcane after five years of cultivation when different amount of straw mulch is removed from the field.

2. Material and methods

The experiment was conducted in an area which belongs to the Bandeirantes Sugar and Alcohol Plant, located in the city of Bandeirantes, latitude 23°06′S, longitude 50°21′W and altitude of 440 m. Based on the Koeppen climatic classification, the climate of the region is Cfa, with an average annual rainfall of 1300 mm. The average annual lighting period is 7.14 h^{-1} day.

The soil water balance (Fig. 1) during the time of research was calculated according to Thornthwaite and Mather (1955). Data for mean monthly and monthly total rainfall was provided by the meteorological station of the Instituto Agronômico do Paraná (IAPAR). The value of available water capacity (AWC) considered was 100 mm.

The soil of the area is classified as Eutroferric Red Latosol (Oxisol) (Empresa Brasileira de Pesquisa Agropecuária, 2013), with a clayey texture. Results from the chemical analysis of the soil carried out in September 2013 at a depth of 0–0.20 m, revealed the following values:

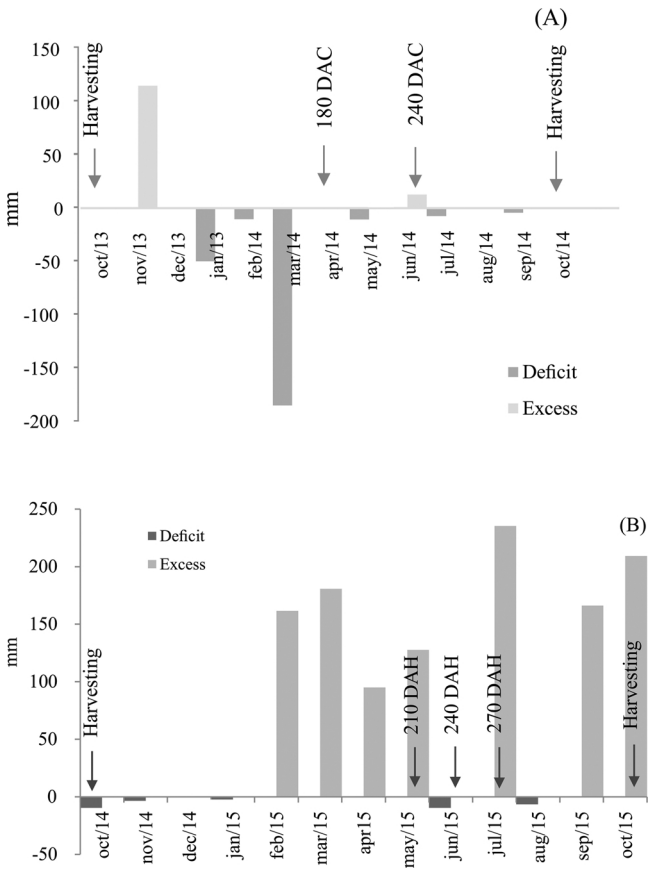

Fig. 1. Monthly water balance during the periods of third (A) and fourth (B) ratoons (harvest 2013/14 and 2014/2015, respectively), Bandeirantes, PR.

pH ($CaCl_2$) 5.8, P (mg dm^{-3}) 36.9, Organic matter (g kg^{-1}) 34.4, Base saturation (%) 81.2; K, Al, Ca, Mg (mg dm^{-3}) 1251; 0,0; 1583; 230.97, respectively and CEC ($cmol_c$ dm^{-3}) 16. The textural analysis showed that soil was composed of 68% clay, 38% sand and 2% silt. No modification or fertilization of soil was necessary based on the chemical analysis of the soil. Weed infestation was extremely low and was controlled manually.

In the experimental area, sugarcane had been grown for the last 65 years, using manual harvesting with straw mulch removal by burning. In 2010, sugar mills adopted the mechanized harvesting system and the same method is adopted in the current experiment Fig. 2.

Sugarcanes (*Saccharum* spp. variety SP 801816) were installed in a randomized block design with 4 replications and evaluated during 4th and 5th cycle (third and fourth ratoon). The experimental plots were

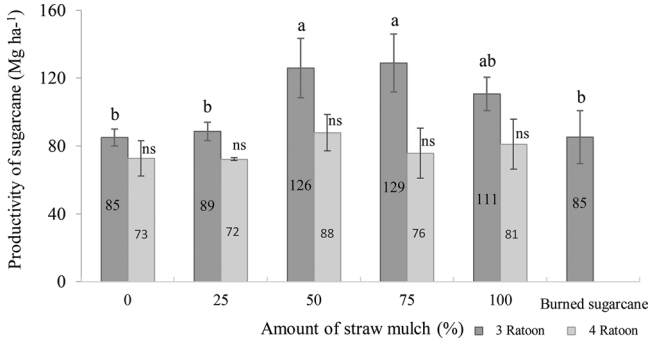

Fig. 2. Sugarcane production (Mg ha^{-1}) in relation to the straw mulch cover over soil surface (%), during third and fourth ratoon cycles (harvests 2013/2014 and 2014/2015, respectively.). The means followed by same letters do not differ significantly from each other, using Tukey test, at 3% probability.